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Exploring the Merits of Perceptual Anticipation in the Soccer Penalty Kick

John van der Kamp

This study investigated whether soccer penalty-takers can exploit predictive information from the goalkeeper's actions. Eight low- and seven high-skilled participants kicked balls in a penalty task with the goalkeeper's action displayed on a large screen. The goalkeeper initiated his dive either before, at or after the ball was struck. The percentage of balls shot to the empty half of the goal was not above chance when the participants could only rely on predictive information. Gaze patterns suggested that the need to fixate the target location to maintain aiming accuracy hindered perceptual anticipation. It is argued that penalty-takers should select a target location in advance of the run-up to the ball and disregard the goalkeeper's actions.

Keywords: Penalty kick, anticipation, action, perception, gaze

Triumph or failure in team sports is determined by the team players' collective efforts. Set play situations stand out, because in contrast to the game's spirit, it is the individual player's performance that is decisive. A prime example is the penalty kick in soccer, in which the penalty-taker is allowed a free kick on goal with only the goalkeeper to prevent him from scoring. Experts and pundits alike are of the opinion that an overwhelming advantage belongs to the penalty-taker, but even among top players a remarkably large percentage of penalty kicks is unsuccessful (i.e., $\approx 20\text{--}25\%$, Jordet, Hartman, Visscher, & Lemmink, 2007; Kropp & Trapp, 1999). As a set play situation, the penalty kick in soccer takes place in a highly predictable environment. Hence, the penalty-taker's skill will be one of the crucial determinants for success, together of course with the penalty-saving prowess of the goalkeeper. To enhance the chance of a successful conversion, the penalty-taker should employ the "best" penalty taking strategy.

A pertinent distinction in that respect is between keeper-dependent and keeper-independent strategies (Van der Kamp, 2006; see also Kuhn, 1988; Morya, Ranvaud & Pinheiro, 2003). In the keeper-independent strategy, the penalty-taker selects the ball's target location in advance and disregards the goalkeeper's actions during the run-up. Normally, the target location is within 180 cm of either goal-post, which is considered to be out of reach of the goalkeeper (Miller, 1996), even though a shot through to the middle may not be unwise either (Bar-Eli, Azar, Ritov,

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Keidar-Levin & Schein, 2007). By contrast, in the keeper-dependent strategy, the penalty-taker makes the final choice of target location by anticipating the side to which the goalkeeper will dive and then places the ball into the opposite side of the goal. Kuhn (1988; see also Bootsma and Savelsbergh, 1988) suggested that the keeper-dependent strategy is prevalent among professional soccer players. Nonetheless, more recently Bar-Eli et al. (2007) reported that the direction of a penalty-taker's kick and a goalkeeper's jump match in approximately 40% of the penalty kicks. They argued that decisions taken by penalty takers' and goalkeepers' are made roughly simultaneously, rather than being completely independent (e.g., the penalty taker observing the goalkeeper's action and only then choosing the side, or vice versa). In other words, it is likely that a considerable number of professional players employ a keeper-dependent strategy, yet it is also obvious that not all do so, or do so successfully (otherwise the correspondence between kick and jump directions would be much closer to zero).

Nonetheless, Van der Kamp (2006; see also Morya et al., 2003) argued that the use of a keeper-dependent strategy can hamper penalty taking performance. In a field experiment, the penalty taking performance of intermediate-level soccer players was evaluated in situations that simulated keeper-independent and keeper-dependent strategies. Participants had to kick the ball at one of two target areas to the right and left of the middle of the goal, dependent on which of two lights placed in the middle of the goal was switched on. In the keeper-dependent strategy condition, participants were informed that the visually specified target area may or may not change at different times during the run-up. A change was signaled by switching off the light that was lit and the concurrent switching on of the second light, indicating that the direction of the kick needed to be altered. In half of the trials the lights in fact changed, whereas in the other half of the trials the lights did not switch and target side thus remained unaltered. By contrast, during the keeper-independent condition participants were told that the visually specified target area would not change. Penalty taking performance was apt to be less than perfect in the keeper-dependent strategy condition. Particularly, it was found that with less than 600–700 ms available to alter kick direction, the use of the keeper-dependent strategy resulted in an enhanced risk of choosing the wrong side. In addition, when participants did in fact correctly modify kicking direction, ball placement was less accurate.

The generalizability of these findings to "real life" penalty taking is somewhat limited, however. The switching off and on of the lights is an abrupt event that served to simulate the final side to which the goalkeeper dived, but does not mimic the goalkeeper's actions in preparation for the dive. It has been argued that before diving a goalkeeper adopts movement strategies that are specific for the intended direction of the dive (Graham-Smith, Lees & Richardson, 1999; Keller, Hennemann & Alegria, 1979; Sánchez, Sicilia, Guerrero & Pugnaire, 2005). In particular, the extension of the knee on the side of the body opposite to the side of the final spring to the ball together with flexion in the other knee, which occurs at 200–250 ms before the penalty taker kicks the ball (Sánchez et al., 2005), has been implicated. In a keeper-dependent strategy, the penalty-taker may exploit these types of predictive information to anticipate the direction of the dive. The absence of any such predictive information in the previous studies (Morya et al., 2003; Van der Kamp, 2006) may have resulted in a substantial underestimation of

the efficacy of the keeper-dependent strategy. The high skilled penalty-takers, in particular, may have been disadvantaged.

Specifically, numerous studies have shown that highly skilled sports players distinguish themselves from their less skilled counterparts in their ability to pick up and use more useful information from the opponent's movement kinematics (e.g., Abernethy, Gill, Parks & Packer, 2001; Ward, Williams & Bennett, 2002; for an overview see Van der Kamp, Rivas, Van Doorn & Savelsbergh, 2008). In soccer, for instance, high-skilled goalkeepers exhibited superior anticipation of the direction of the penalty kick, but only in experimental viewing conditions that prevent participants from viewing the moment the penalty-taker contacts the ball and subsequent ball flight (Williams & Burwitz, 1993). The implication is that the high-skilled goalkeepers are better tuned to information available from the movements of the penalty-taker before ball-contact (see also Franks & Harvey, 1997; Poulter, Jackson, Wann & Berry, 2005; Savelsbergh, Williams, Van der Kamp & Ward, 2002; Savelsbergh, Van der Kamp, Williams, & Ward, 2005; cf. Dicks, Button, & Davids, 2010). Likewise, high-skilled penalty-takers who employ a keeper-dependent strategy may be better tuned to predictive information that is available from the preparatory movements that the goalkeeper makes before initiating the final spring for the ball (Sánchez et al., 2005). Until now, the benefits of anticipation in penalty taking have not been investigated.

Yet, anticipating the side to which the goalkeeper is going to dive may turn out to be disadvantageous, because it may hinder the penalty-taker in looking at the ball's target location. Research has shown that the spatial accuracy of a broad range of actions is significantly enhanced by looking at the target before movement execution (e.g., Land & Hayhoe, 2001; Land, Mennie & Rusted, 1999). Firstly, directing gaze at the target provides visual information that can guide an action. For example, Vickers (1996) argued that aiming accuracy in a basketball free throw benefits from a prolonged fixation on the target, because it allows exploitation of important information about target location that is crucial to control the action. Secondly, the production of the eye movements itself may promote the accuracy of the action. Wilson, Stephenson, Chattington and Marple-Horvat (2007) showed, for instance, that moving the eyes promoted steering performance in simulated driving even when vision of a bend in the road was denied. This suggests that nonvisual information made available by the eye movements (e.g., efference copy or proprioceptive information from the eye muscles) contribute to ensure accurate spatial control of the aiming action (see also Marple-Horvat, Chattington, Anglesea, Ashford, Wilson & Keil, 2005).

Nagano, Kato and Fukuda (2006) reported gaze patterns of skilled football players who kicked balls at a target at 7 m distance. Initially gaze was directed at the target, but shifted to the ball while the players approached the ball. Just prior and during the execution of the kicking movement gaze was redirected to the target. The importance of this final gaze at the target was underlined by the finding that its duration correlated with kicking accuracy. In a penalty-kick situation, however, this gaze pattern may be disrupted when the penalty-taker uses a keeper-dependent strategy. To anticipate the side the goalkeeper is going to dive, the penalty-taker may continue looking at the goalkeeper rather than making a final fixation to the ball's target location. Findings by Bakker, Oudejans, Binsch and Van der Kamp (2006) and Wilson, Wood and Vine (2009) indeed point to potentially adverse effects of

such a strategy. In these studies, participants were asked to perform penalty kicks at either a stationary goalkeeper projected on a large screen (Bakker et al., 2006) or to shoot at a goalkeeper who was instructed to try and save the ball, but not to move before the ball was struck (Wilson et al., 2009). The results revealed a strong correlation between direction of gaze and penalty kick accuracy: participants were much more likely to kick the ball within the goalkeeper's reach when they looked at the goalkeeper than when they directed gaze at the target areas next to goalkeeper. Unfortunately, however, a goalkeeper that stands still until the ball is contacted may not provide much information that can be capitalized upon by a penalty-taker who uses a keeper-dependent strategy (cf. Masters, Van der Kamp & Jackson., 2007; Van der Kamp & Masters, 2008). It is therefore hard to judge whether the potentially disadvantageous effects on kicking accuracy of viewing the goalkeeper outweigh the benefits of choosing the side opposite to the goalkeeper's dive.

In the present experiment, I investigated whether penalty-takers who use a keeper-dependent strategy can exploit information from the goalkeeper's preparatory postures and movements to anticipate the side the goalkeeper dives. To this end, low-skilled and high-skilled soccer players kicked balls in a penalty simulation task with the goalkeeper's actions displayed on a large screen. A modified version of the occlusion technique to investigate perceptual anticipation was used in which the temporal coordination between the penalty-taker's actions and the goalkeeper's actions was manipulated. Instead of providing verbal judgments or making pantomimed actions, as is commonly done in studies investigating perceptual anticipation, the participants produced genuine kicks. This is a significant modification as Dicks et al. (2010; see also Van der Kamp et al., 2008; Van Doorn, Van der Kamp, de Wit & Savelsbergh, 2009) found that gaze patterns and information pick up are crucially different depending on the functional task demands. In three conditions, the goalkeeper initiated the dive before, at or after the penalty-taker contacted the ball. Consequently, penalty-takers were dependent on predictive information from the goalkeeper's preparatory movements and postures in those conditions in which the goalkeeper made his final move relatively late in relation to the moment the penalty-taker strikes the ball (i.e., "at"- and "after"-conditions). I hypothesized that if predictive information can be used, then penalty-takers, particularly the high-skilled, should be able to kick the ball to the opposite side of the goalkeeper's dive, not only in the "before"-condition but also in the "at"- and "after"-conditions. By measuring the penalty-takers' gaze patterns, I also pursued the hypothesis that perceptual anticipation of the direction of the goalkeeper's dive may be adversely affected because the preservation of kicking accuracy requires fixation of the ball's target area.

Method

Participants

Eight low-skilled (mean age = 22.0, $SD = 1.5$ years) and eight high-skilled (mean age = 26.0, $SD = 4.0$ years) male right-footed soccer field players, including defensive players, midfield players and forward, volunteered to participate in the study. The low-skilled participants played soccer at a recreational level. Seven of the participants in the high-skilled group played in the top district or national amateur

leagues of the Dutch football association. The eighth participant played professional football in the Dutch premier league. Participants reported to regularly take penalty kicks during matches and practice. Reliable records of the participants' penalty take performance were not available. The volunteers gave their written consent before the experiment and were treated in accordance with the local institution's ethical guidelines.

Test Video

The test video was produced with the help of one volunteer goalkeeper and two volunteer right-footed penalty-takers, all competing at top district level. The penalty-takers were instructed to take the penalty kicks as they would in normal competition; however, using a keeper-dependent strategy. They were unaware of the instructions for the goalkeeper. To imitate the different strategies that a goalkeeper might use during a penalty kick, the goalkeeper received three sets of instructions: i) to act as he would in normal competition (e.g., try to determine the side to which the ball is shot), ii) to act thus that it would entice the penalty-taker to select the side the goalkeeper intended to dive, and iii) to dive to either the left or right side. The goalkeeper was filmed from the perspective of a penalty-taker with a digital video camera (JVC, GY-DV500) positioned 0.5 m to the right of the penalty spot. The recordings were then edited with the use of Pinnacle software (Studio 9.0), resulting in a total of 45 test clips of 3 s duration each. Three types of clips were made, which either showed the goalkeeper initiating his dive for the ball after 1.25, 2.0, or 2.5 s from the start of the clip. Each clip included the goalkeeper's movements and postures in preparation for the dive, the dive, and the goalkeeper lying on the ground.

Apparatus

The participant's task was to shoot a foam ball ($\varnothing = 0.19$ m) at a screen at which the video clips with the goalkeeper's actions were projected. The clips were back-projected (EIK CC-7000) using a reflective surface to increase image size onto a large screen (2.29×2.27 m). Plexiglas in front of the screen served as protection. The projected goal width was 2.27 m and the ball was placed at 3.44 m, thereby maintaining the relationship between goal width (7.32 m) and penalty spot distance (11 m). At the same time, however, it was deemed important to closely mimic the visual angle subtended by the goalkeeper on the penalty-takers retina. Given the screen size, the latter requirement could only be fulfilled by projecting a relatively narrow goal, not unlike an indoor soccer goal (Figure 1). In effect, the projected goalkeeper reached the edges of the screen (i.e., the goal posts) when diving. (This probably made the accuracy demands of the task more difficult than in normal penalty kicking.) At the beginning of each trial, the first frame of the clip was displayed. The playing of the clip was triggered when the participant interrupted a light beam of an Opto-switch (E3S-R 30E4 Omron) positioned two meters behind the ball at ankle height, which indicated the participant's start of the run-up to the ball. Gaze behavior was recorded using an Applied Science Laboratories (ASL) 501 eye-tracker system. This is a video-based monocular system that measures eye-line of gaze using head-mounted optics. The accuracy of the system was ± 1

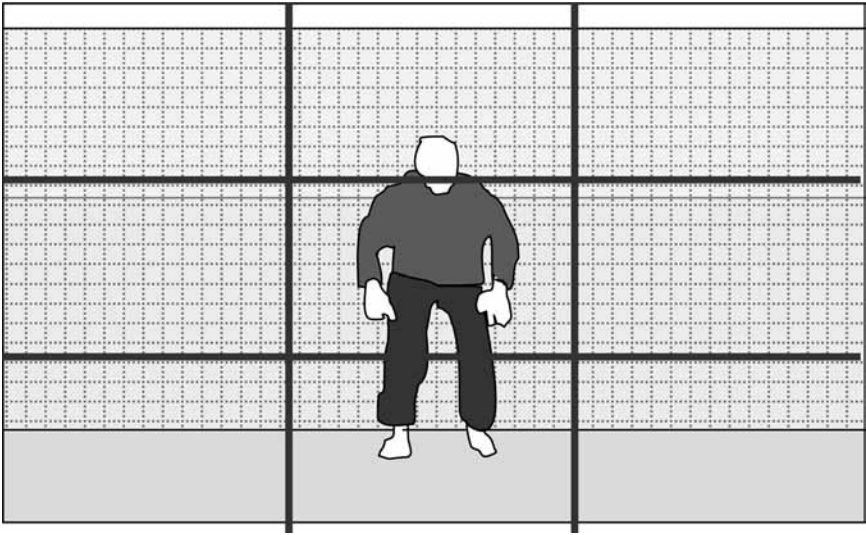


Figure 1 — A sketch of the first frame of a video clip. Relative sizes of the goal and goalkeeper are maintained. The lines indicate the nine areas that were used for analyzing the ball and gaze locations.

degree visual angle (see Savelsbergh et al., 2002). The calibration of the system was checked every trial and if necessary the system was recalibrated; however, as a rule it was recalibrated after every 9th trial. An IRED connected to the Opto-switch was attached to “scene” camera of the ASL to synchronize gaze recordings with the start of the participant’s run-up. A digital video camera (Canon, XM1, 25 Hz) recorded foot-ball contact and the projection screen.

Procedure and Design

The participants started with a short training session during which they were instructed to kick the ball at exactly two seconds after they had started the run-up in one smooth action without any interruption, and to the side opposite to which the goalkeeper dived. The aim of this practice session was to learn to kick the ball approximately 2 s after they had interrupted the light beam at the start of the run-up. With a two second approach, the moment the participant made foot-ball contact and the moment the displayed goalkeeper started his final spring would be optimally synchronized (i.e., the video clip was triggered by the participant interrupting the beam). To provide feedback on the duration of the run-up, an auditory cue was inserted on the video clip after exactly 2 s. In addition, the experimenter provided verbal feedback whether foot-ball contact coincided with the auditory cue. Participants received at least ten practice trials. For the experimental trials, the moment of ball contact occurred on average 2.19 s ($SD = 0.12$ s) after the participants interrupted the light beam. The moment of ball contact did not differ

as a function of the moment the keeper dived (i.e., “before” vs. “at” vs. “after”) or skill level. With clip durations of 1.25, 2 and 2.5 s (see above), this resulted in three experimental conditions: the “before”-condition (i.e., goalkeeper’s dives at approximately 0.95 s before ball contact, providing predictive information plus information from the dive itself), the “at”-condition (i.e., dive at approximately 0.2 s before contact, providing early and late predictive information, see Sánchez et al., 2005) and the “after”-condition (i.e., dive at approximately 0.3 s after contact, providing only early predictive information).

During the experiment 15 video clips from the “before”-, “at”-, and “after”-conditions were randomly presented, resulting in a total of 45 trials. Participants were instructed to score a goal. Specifically, they were instructed to shoot the ball to the side opposite to which the goalkeeper dives. In addition, they were told to kick the ball approximately two seconds after the start of the run-up. It was emphasized however that the spatial demand was most important. In the case the participant was visibly too late or early, the participant was told and the trial was discarded.

Data Analysis

Penalty taking performance was assessed from the video recordings. The projected goal was split into nine areas, each having the same size ($0.43 \text{ m} \times 0.75 \text{ m}$; Figure 1). For each trial two performance measures were derived: 1) the proportion of balls shot to the correct side, and 2) the proportion of balls missed. A ball shot to the correct side was defined as a ball that was directed to the side opposite to which the goalkeeper dived irrespective of whether the ball landed in the goal area or was shot wide of the goal or above the crossbar. A ball missed was defined in terms of spatial and temporal accuracy. That is, to be categorized as a spatial miss the ball must land outside one of the nine goal areas (e.g., a ball shot wide or above the crossbar), whereas for a temporal miss the ball must land within one of the nine goal areas but at the same moment or after the goalkeeper moved into that area (i.e., a ball that lands on a goal area before the goalkeeper is defined as incorrect, but not as a miss). The individual means of these measures were submitted to a 2(group: low-skill vs. high-skill) by 3(moment of dive: before vs. at vs. after ball contact) ANOVA with repeated measures on the last factor. In the case that the sphericity assumption was violated (i.e., for η smaller than 1.0), the Huyn-Feldt adjustment of the p-values is reported. Post hoc pairwise comparisons were conducted using the Bonferroni correction procedure to keep the Type I error rate to the 5% level, and η^2 was used as the measure of effect size. Following Cohen (1988), $\eta^2 > 0.14$ defined the minimum threshold for an effect size that was large, and was considered to represent a meaningful difference between conditions.

Point of gaze was assessed through the percentage of viewing time, which was defined as the proportion of time the participant spent viewing to various locations when trying to anticipate the goalkeeper’s dive. The ASL-data were analyzed frame-by-frame at 25 Hz using a Sony DHR-1000VC digital video recording. Commonly, point of gaze comprises the coding of fixations (sometimes including pursuit movements), a fixation being operationally defined as a period of time equal or longer than 100 ms when eye movements remain stationary within an area that corresponds in angular size with the fovea. The coded fixations then

serve as a basis for calculating the number and duration of the fixations and the percentage of viewing time spent fixating on various areas (e.g., Abernethy & Russell, 1987; Helsen & Pauwels, 1993; Savelsbergh et al., 2002; Williams, Davids, Burwitz, & Williams, 1994). Nevertheless, there is ample evidence demonstrating that a shorter visual presentation of an event (i.e., 30–50 ms) can affect movement control even when participants are unable to consciously perceive the event (Fellows, Tabaza, Heumann, Klotz, Neumann, Schwarz, Noth & Töpper, 2002; Klotz & Neumann, 1999; Taylor & McCloskey, 1990). For example, the presentation of a visual stimulus followed after a short interval (e.g., 50 ms) by the presentation of a similar but larger stimulus is not consciously perceived. However, if the smaller stimulus provides information for executing a particular action, reaction times are shortened in accordance with the masked smaller stimulus (Taylor & McCloskey, 1990). In other words, information can be picked up within much shorter periods of time than the commonly defined 100 ms, particularly in the context of action (see also Van der Kamp et al., 2008; de Wit, van der Kamp, & Masters, 2011). For that reason the proportion of time the participant spent viewing to various locations reported here includes all 40 ms frames. Hence, the analysis is not restricted to frames that belong to conventionally defined minimum fixation durations (see also Bakker et al., 2006)¹.

The following areas were distinguished: 1) the goalkeeper's upper body (i.e., head, arms and trunk), 2) the goalkeeper's lower body (i.e., hip, legs and feet), 3) the left and right goal areas between the keeper and the posts (i.e., the two outer thirds of the projected goal), 4) the goal area directly surrounding the keeper (i.e., the middle third of the projected goal), 5) the floor between the screen and the ball, including the ball, 6) other (i.e., areas above the bar, next to the post, and floor areas not included in 5)². To determine whether the areas to which the participants directed gaze varied across different stages of the penalty kick, the data were grouped into three time periods working backward from the moment of ball contact. The first period lasted from 240 ms before the moment of ball contact to ball contact. Prior work (Franks & Harvey, 1997; Lees & Nolan, 1998) showed that the instep drive, starting with the final placement of nonkicking foot, takes approximately 250ms. In addition, it is almost impossible for the penalty-taker to alter the kicking direction in this stage of the penalty kick (Van der Kamp, 2006; see also Morya et al., 2003). The second time period lasted from 720 to 240 ms before ball contact. This period was chosen because the earliest failures to adjust kicking direction were found to occur from approximately 700–750 ms before ball contact (Van der Kamp, 2006). The third period consisted of the early phase of the run-up and lasted from 1920 to 720 ms before ball contact.

The percentage of viewing time data were analyzed using a 2(group: low-skill vs. high-skill) by 3(moment of dive: before vs. at vs. after ball contact) by 3(time: 1920–721 vs. 720–241 vs. 240–1 ms before ball contact) by 6(area: upper body vs. lower body vs. outer goal areas vs. middle goal area vs. floor area vs. rest) ANOVA with repeated measures on the last three factors. Again, Huyn-Feldt adjustment of the *p*-values are reported in the case the sphericity assumption was violated. Post hoc comparisons were conducted using the Bonferroni correction procedure and η^2 was used as the measure of effect size.

Results

Penalty Taking Performance

One high-skilled player seemed not to perform to the best of his abilities and missed more than 45% of the balls, many of which were shot wide. In comparison, even the worst low-skilled player only missed 35%. This high-skilled participant was therefore excluded from further analysis.³ The moment the goalkeeper dived had a highly significant effect on the percentage of balls shot to the correct side ($F_{2,26} = 22.7, p < .001, \eta^2 = 0.64$, Figure 2a). Post hoc tests indicated that a larger proportion of balls was shot to the correct side when the goalkeeper dived before foot-ball contact than when the keeper dived at or after contact (P 's < 0.001). The latter two conditions did not differ ($p = .54$). The participants shot only above chance to the correct side when the goalkeeper dived before ball contact ($t_{14} = 23.9, p < .001$). There was neither a significant effect for group ($F_{1,13} = 0.00$) nor for group \times moment of dive interaction ($F_{2,26} = 0.54$). The clips showed the goalkeeper using different saving strategies. The goalkeeper anticipated the direction of the kick, dived to a side irrespective of the penalty-takers action, or tried to entice the penalty-taker to select the side the goalkeeper intended to dive. The percentage of balls shot to the correct side, however, was not differentially affected by these goalkeeper strategies ($F_{2,26} = 0.57$).

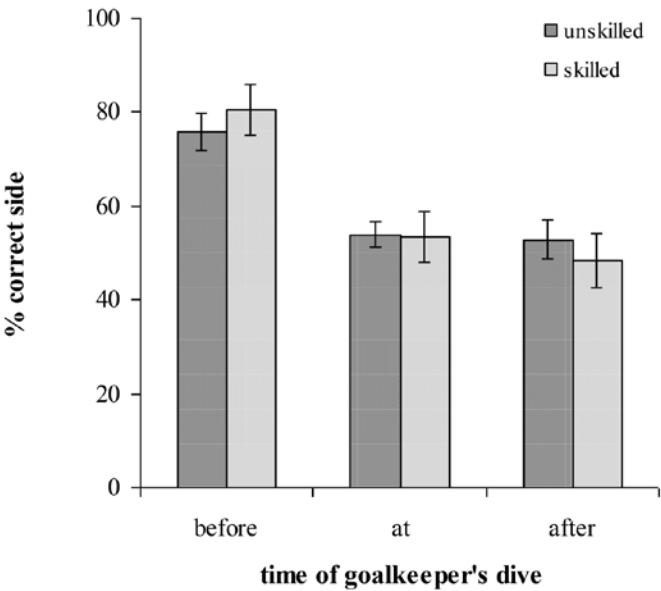


Figure 2 — The percentage of balls shot to the correct side as a function of the time of the goalkeeper's dive and skill level. Error bars indicate standard error.

The results for the percentage of missed balls showed, however, that more balls directed to the side opposite to which the goalkeeper dives did not necessarily lead to scoring more goals. On the contrary, most misses appear to occur when the goalkeeper dived early (Figure 3). Nonetheless, the total percentage of missed balls was not significantly affected by the moment of dive ($F_{2,26} = 2.89$, $p = .07$, $\eta^2 = 0.18$). A significant main effect of group ($F_{1,13} = 9.14$, $\eta^2 = 0.42$) indicated that the low-skilled participants made more misses than the high-skilled players. There was no interaction between the two factors ($F_{2,26} = 0.15$). The percentage of temporal misses was significantly affected by moment of dive ($F_{2,26} = 6.68$, $p < .01$, $\eta^2 = 0.34$), indicating that more temporal misses were made when the goalkeeper started diving before ball contact (P 's < 0.05). Figure 3 suggests that this effect was a little more pronounced among the low-skilled players, albeit that the moment of dive \times group interaction failed to reach significance ($F_{2,26} = 3.23$, $p = .06$, $\eta^2 = 0.19$). It was found, however, that the low-skilled players made more temporal misses than the high-skilled players ($F_{1,14} = 5.78$, $p < .05$, $\eta^2 = 0.29$). For the percentage of spatial misses only a main effect of group was revealed ($F_{1,13} = 4.78$, $p < .05$, $\eta^2 = 0.27$). The low-skilled players had more spatial misses than the high-skilled players (Figure 3).

Gaze Behavior

The ANOVA for the percentage of viewing time revealed significant effects for area ($F_{5,65} = 3.61$, $p < .05$, $\eta^2 = 0.20$), time \times area ($F_{10,130} = 13.09$, $p < .001$, $\eta^2 = 0.50$), moment of dive \times area ($F_{10,130} = 2.30$, $p < .05$, $\eta^2 = 0.15$), and time \times moment of dive \times area ($F_{20,260} = 1.90$, $p < .05$, $\eta^2 = 0.13$). The effects are illustrated in Figure 4. At the start of the run-up gaze was directed at the goalkeeper's upper and lower body. As the run-up evolved, progressively less time was directed at the keeper's upper body parts. During the actual execution of the kick, shortly before ball contact, gaze moved away from the goalkeeper's lower body to the open goal areas. There was some suggestion that during this phase participants spent less time viewing at the outer goal areas and more time at the middle goal areas in the "before"-condition as compared with the "at" and "after"-conditions (i.e., 25.5%, 32.5% and 31.7% at the outer areas and 28.9%, 18.7% and 20.5% at the middle area for the "before"-, "at"-, and "after"-conditions, respectively). However, the effect size associated with these differences was moderate (i.e., $\eta^2 = 0.13$). The differences in gaze behavior were not mediated by skill level.

Discussion

The typical study on penalty kick strategies involves observational analysis of penalties taken at World or European Cup tournaments (e.g., Jordet et al., 2007; Jordet & Hartman, 2008; Kuhn, 1988; Masters et al., 2007). Masters et al. (2007), for instance, observed that goalkeepers nearly always stand off-center, and remarkably, that the penalty kicks were more frequently directed to the side of the goalkeeper on which there was more space (i.e., means 59% versus 41%). Apparently, many expert soccer players use a keeper-dependent strategy, in which their final decision on the direction of ball placement is influenced by the goalkeeper's posture and movements. During the run-up, the penalty-taker tries to obtain information from

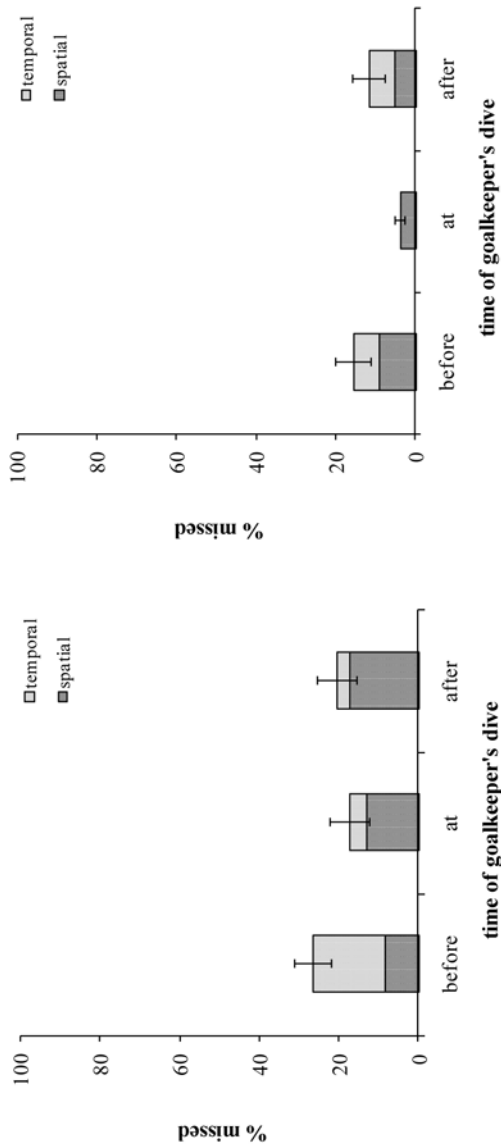


Figure 3 — The percentage of balls missed separated for temporal and spatial errors as a function of the time of the goalkeeper’s dive. Low-skill and high-skill group are shown in the left and right panel, respectively. Error bars indicate standard error.

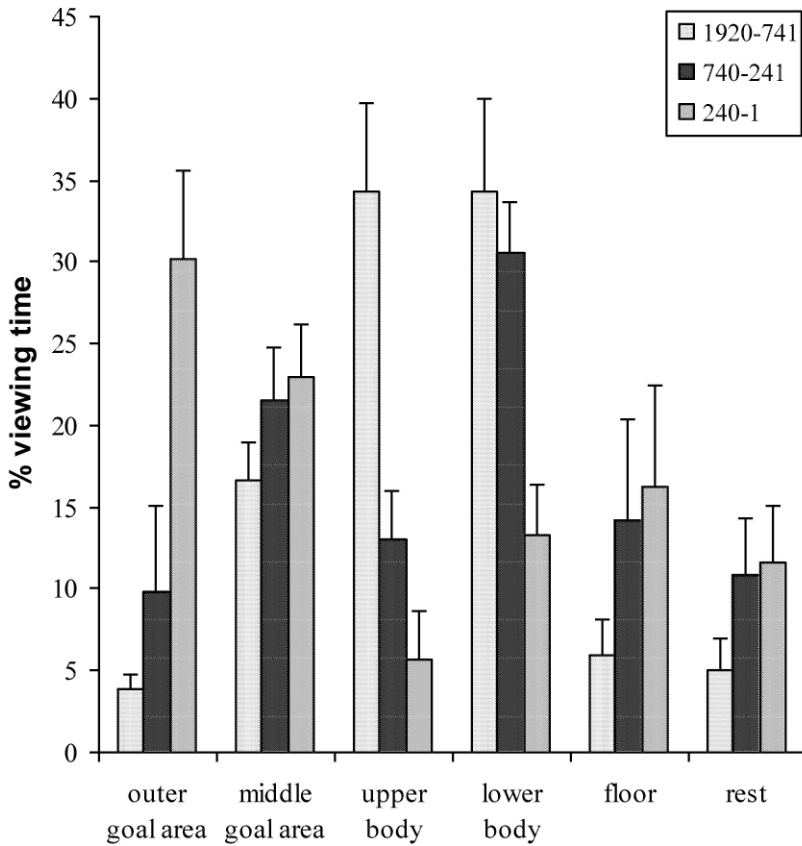


Figure 4 — The proportion of time spent viewing at each fixation area across the three phases of the run-up as a function of the time of the goalkeeper's dive. The moment of ball contact is at 0 milliseconds. Error bars indicate standard error.

the goalkeeper's preparatory actions in an attempt to anticipate which way the goalkeeper will dive. If successful, anticipation results in the penalty taker placing the ball to the empty side of the goal.

Notwithstanding the intuitive logics and widespread belief of its superiority, previous experimental work revealed an important caveat of the keeper-dependent strategy, namely the time needed by the penalty-taker to alter the direction of the kick (Morya et al., 2003; Van der Kamp, 2006). It was found that with less than 600–700 ms available to complete the kick the likelihood that the ball can be directed opposite the side to which the goalkeeper dives is reduced to chance level. In addition, the shots that were directed to the correct side were less accurate. The generalizability of these findings remained uncertain, because the absence of a goalkeeper in these previous studies did not allow the participants to anticipate

which side to shoot the ball. Yet, the current study further highlights the risks associated with the keeper-dependent strategy. The main finding here is that even with a diving goalkeeper present, the efficacy of the keeper-dependent strategy turns out to be relatively low. In the two conditions where the participants could only rely on predictive information sources, that is when the goalkeeper initiated the final spring approximately at or after the participant contacted the ball, the number of balls shot to the empty half of the goal did not exceed chance level. Both the low- and high-skilled players were unable to gain an advantage from the partial or incomplete advance sources of visual information that were available from the goalkeeper's preparatory movements and postures before the dive. Only when the goalkeeper committed himself early (in the current study on average at 950 ms before ball contact) were participants more successful in kicking the ball to the side opposite to which the goalkeeper dived. In line with previous findings (Van der Kamp, 2006), there was a potential cost involved in terms of actually converting a goal; although the participants directed the ball more often to the empty side of the goal, they did not score more goals. To the contrary, many of the balls that were (incorrectly) directed to the same side as the goalkeeper passed the goal line only after the goalkeeper had moved into the area the ball was shot.

Why were participants not better able to perceptually anticipate the direction in which the goalkeeper intends to dive? The least interesting explanation might be the idiosyncrasies of the goalkeeper. With only one goalkeeper involved, such a possibility cannot be ruled out completely. However, biomechanics dictates an extension of the knee on the side of the body opposite to the side of the final spring to the ball and flexion in the other knee. Sánchez et al. (2005) identified these preparatory movements in 218 of 222 penalty saving attempts among 12 amateur and professional goalkeepers. It is therefore unlikely that these sources were not available from the present goalkeeper, implying that both the low-skilled and the high-skilled participants were unable to exploit them. Hence, rather than the idiosyncrasies of the goalkeeper, it must be perceptual constraints that hamper anticipation in penalty taking. Specifically, the current experiment did not provide evidence that either the low- or high-skilled players were able to use the predictive information that specifies the goalkeeper's intentions before the actual dive to one or the other side.

The following, not mutually exclusive scenarios can be envisaged. First, the penalty-takers may not have detected the predictive information, because they were not attuned to it. Neither group of participants performed above chance when only predictive information was available. This lack of any obvious perceptual anticipation is intriguing, in particularly for the high-skilled players. Perhaps their penalty taking skill did not match their general soccer expertise, although the high-skilled players did miss significantly fewer penalty kick than their low-skilled counterparts (for a similar argument for penalty saving skill among high-skilled goalkeepers see Savelsbergh et al., 2005). For instance, Jordet et al. (2007) reported that forward are more likely to score a penalty kick than midfielders and defenders. Not all of the present high-skilled participants were forward however. In addition, although actual kicks were produced, which presents a significant progress over prior investigations of perceptual anticipation that employed the occlusion technique, the experimental procedures may still have comprised anticipation skills, especially for the high-skilled players. Not every high-skilled participant may

commonly use the keeper-dependent strategy that was enforced upon them and also the spatio-temporal constraints (i.e., a predefined 2 m run-up in 2 s) of the task may have presented difficulties for retention of penalty taking skill, including the ability to detect and use predictive information. A final important limitation concerning representative design is the absence of direct interactions between goalkeeper and penalty-taker (Lopes, Araujo, Peres, Davids, & Barreiros, 2008). For instance, some penalty-takers perform a stutter kick or “paradinha” action, in which the kicking action is briefly interrupted, to elicit an early movement of the goalkeeper⁴. Future work is necessary to address these possible design limitations. Preferably, this work also takes other likely competitive factors into account such as anxiety, fatigue and distraction (see e.g., Jordet & Hartman, 2008; Jordet et al., 2007; Wilson et al., 2009).

Second, the penalty-takers may not have detected the predictive information, because accurate aiming necessitates a gaze fixation at the target area shortly before the ball is kicked (e.g., Bakker et al., 2006; Land et al., 1999; Land & Hayhoe, 2001; Wilson et al., 2007, 2009). That is, the present findings indicate a gaze pattern that comprises viewing the goalkeeper’s upper body during the early phase of run-up and a subsequent shift of gaze to the hip, limbs and feet areas. It is probably during this phase that the penalty-takers try to gather information about the side to which the goalkeeper is going to dive (Sánchez et al., 2005). Yet, when the penalty kicker actually executes the instep drive in the final phase of the run-up (i.e., the last 240 ms before ball contact), there is a dramatic increase in gaze directed at the ball’s target areas. This gaze pattern seemed anchored to the penalty-takers run-up, rather than to the goalkeeper’s actions. That is, its occurrence was relatively independent of the moment the goalkeeper dived. The only departure perhaps occurred when the goalkeeper committed himself early, when participants also tended to direct gaze to the areas in the middle of the goal, which was accompanied by a decrease in shot accuracy. Clearly, the relatively consistent shift away from the goalkeeper toward the target area (and perhaps the ball as is indicated by the increase in time spent viewing at the floor) during the final phase of run-up to the ball stops the pick up of information specifying the goalkeeper’s actions. And yet, it is during this period between 250–200 ms before the penalty-taker contacts the ball that pertinent predictive information from the preparatory movements of the goalkeeper (i.e., the extension of the knee on the side of the body opposite to the side of the final spring to the ball together with flexion in the other knee) is most likely to come available. In short, it seems that the keeper-dependent penalty kick strategy presents the player with two conflicting perceptual requirements. To anticipate the side to which the goalkeeper intends to dive, the penalty-taker must direct gaze to the goalkeeper, whereas at the same time, gaze must be directed at the target area to secure accurate ball placement. In the current study, anticipation may have been hampered because the participants favored looking at the target location at the final critical phase of the run-up. Finally, at 250 ms before the initiation of the dive the predictive sources of information would come available too late to be of any use for the penalty-taker to make any changes in the direction to which to kick the ball. Due to the minimum time required to alter the kicking action in response to a change in target location, the information can only interfere with the proper execution of the instep drive (Morya et al., 2003; Van der Kamp, 2006). The higher proportion of misses in the case that the goalkeeper dives early supports this interpretation.

To conclude, the limitations concerning representative design must not be taken too lightly, but the current study does suggest that the opportunity to anticipate to which side the goalkeeper intends to dive does not dramatically increase the efficacy of the keeper-dependent strategy. The penalty-takers did not show any signs of exploiting predictive information for anticipation, except when the goalkeeper initiates the final dive relatively early in the run-up (as high-skilled penalty savers usually do not do [Savelsbergh et al., 2002]); however, this may go together with a less accurate and less powerful kick. It seems that except constraints arising from action (i.e., time required to adjust the kick), also perception imposes constraints on successful adoption of the keeper-dependent strategy. In particular, conflicting requirements to direct gaze at the goalkeeper and the target area at the final phase of the run-up may impede the efficacy of the keeper-dependent strategy. In addition, the predictive information from the preparatory movements of the goalkeeper may arise too late to be used or require extensive learning to pick up (e.g., Jackson, 2005). On the practical side, each individual penalty-taker has to weigh the benefits of the keeper-dependent strategy against its drawbacks. Nonetheless, based on the empirical research to date, the risk associated with the use of the keeper-independent strategy seems smaller. Employing the keeper-independent strategy implies that practice should focus on shot accuracy without being distracted by the goalkeeper's actions. The penalty-taker may also benefit from learning to make accurate gaze fixation at the target location, just before and during the execution of the kick. The goalkeeper, by contrast, is advised try to take the actions of the penalty-taker into account and certainly not to move too early.

Notes

1. For the record, the percentage of viewing time for the various locations was also analyzed using the fixation data only. That analysis revealed (statistically and numerically) similar patterns of gaze.
2. Due to technical error (e.g., failure of the Opto-switch) 45 out of a total 720 trials were excluded from the analyses. Missing data frames within the remaining trials (e.g., blinking, eye movements in depth) amounted to a total of 7.3%. There was a significantly higher proportion of missing data in the "before"-condition (i.e., 9.2%).
3. The removal of this high-skill participant did not critically affect the pattern of results. Except for the reported group main effects for the percentage of missed balls and the spatial misses, both of which would just have failed to reach significance were the participant included in the analyses, no further disparities resulted.
4. I thank the anonymous reviewer for pointing out the "paradinha" action as an example of a keeper-dependent strategy.

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